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ABSTRACT

This guide and accompanying videotape are a product of the seminar "Analyzing the Teaching of Mathematics in Japan and the United States" held in Tokyo, Japan, following the 9th International Congress of Mathematical Education in August, 2000. The purpose is to introduce the concept of Japanese lesson study to the American mathematics education community. The videotape captures the essential elements of lesson study such as collaborative planning, lesson observation, analytic reflection, and ongoing revision. The User's Guide supplements the videotape by providing some background information about lesson study and implications for professional development in the United States. The guide also contains some resource materials including a translation of the detailed plan of the grade 2 lesson featured in the videotape, a translated transcription of excerpts of dialogue between a teacher and his pupils that occurred during the lesson, a selected bibliography and a list of lesson study web sites, and templates summarizing ideas related to Japanese lesson study that are ready for use at professional development sessions. (KHR)

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A User's Guide to
Japanese Lesson Study
Ideas for Improving Mathematics Teaching

Frances R. Curcio

National Council of Teachers of Mathematics

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NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS

A User's Guide to

Japanese Lesson Study

Ideas for Improving Mathematics Teaching

Frances R. Curcio

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City University of New York,
Flushing, New York

National Council of Teachers of Mathematics
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PREFACE

The videotape *Japanese Lesson Study: Ideas for Improving Mathematics Teaching* is a product of a seminar, Analyzing the Teaching of Mathematics in Japan and the United States, held in Tokyo, Japan, following the Ninth International Congress of Mathematical Education in August, 2000, and funded by a grant to the National Council of Teachers of Mathematics by the National Science Foundation. A list of the seminar participants can be found in Appendix 1.

The purpose of the videotape is to introduce the concept of Japanese lesson study to the American mathematics education community. Lesson study can be used for preservice teacher preparation and in-service professional development. However, implementing the ideas of Japanese lesson study will entail more than a simple transplant. The culture of American schools and the design of appropriate professional development opportunities based on teachers' needs must be considered before implementing lesson study ideas. Although the hope is that essential teacher-driven characteristics of lesson study (e.g., collaboration, observation, analytic reflection) will remain, some adjustments and modifications will be inevitable (see, e.g., West and Curcio [in review]). As with all aspects of teaching, not just one way exists to accomplish professional development. This *User's Guide* contains some suggestions, and it is *not* meant to be prescriptive (see "Suggestions" below).

In the videotape, attempts have been made to capture the essential elements of lesson study (i.e., collaborative planning, lesson observation, analytic reflection, and ongoing revision; see Appendix 2 for a template). This *User's Guide* was developed to supplement the videotape by providing some background information about lesson study (see the section "What Is Japanese Lesson Study?") and implications for professional development in the United States (see the section "Can Lesson Study Work for *Us?*"). The guide also contains some resource material: a translation of the detailed plan of the grade-2 lesson (taught by Kozo Tsubota at the University of Tsukuba Elementary School for the National Group for the Mathematics Lesson Study Conference on Wednesday, August 9, 2000) featured in the videotape; a translated transcription of excerpts of dialogue between Mr. Tsubota and his pupils that occurred during the lesson; a selected bibliography and a list of lesson study Web sites; and tem-

plates (see Appendixes 2 and 3) summarizing ideas related to Japanese lesson study, ready for use at professional development sessions.

Some Suggestions for Using the Videotape and *User's Guide*

Designed to introduce Japanese lesson study, the videotape can be used with in-service and preservice mathematics teachers who are interested in learning about Japanese lesson study and are considering adapting it for their use. After asking the teachers to share what they know about Japanese lesson study and recording their thoughts for projection by means of a computer, overhead projector, or chalkboard, the videotape (duration 7 minutes, 25 seconds) can be shown. A discussion of the key ideas could follow, referring to or projecting a slide of Appendix 2. The content and form of the grade-2 lesson plan (see pages 9–14) can be analyzed to prompt a discussion of planning and lesson development. To exemplify the discourse or interactions between Mr. Tsubota and his pupils, sections of the transcripts (see pages 15–21) can be distributed and discussed.

Groups of three or four teachers may want to form study groups to discuss their curriculum and plan a lesson together. The planning phase should not be rushed. Goals and objectives need to be carefully discussed and formulated before designing instructional tasks and activities and anticipating students' reactions. The Lesson Study Protocol (see Appendix 3) may be useful in establishing guidelines for observation and postlesson discussion. To help observers focus on different aspects of the lesson, observation tools are also recommended (Artzt and Armour-Thomas 2002) and can be used to complement the lesson study activities.

Lesson study ideas can also be used with preservice teachers in a methods course or in a field component of a methods course. After viewing and discussing the videotape, groups of three or four preservice teachers can be assigned to study a topic from the mathematics curriculum of a given grade, formulate goals and objectives for instruction, and develop a lesson plan together. Again, this planning phase should not be rushed. Then during peer teaching or microteaching, each preservice teacher can be given the opportunity to teach the lesson following various iterations based on feedback and analytic reflection. These experiences, supported by tools for observation and self-assessment

(Artzt and Armour-Thomas 2002), contribute to developing reflective practitioners.

As mentioned previously, these suggestions are not meant to be prescriptive. Viewers are encouraged to adapt these materials to meet their own needs for designing professional development experiences.

Acknowledgments

The preparation of the videotape and this *User's Guide* would not have been possible without the assistance and support of many people. In particular, many thanks are due to Rich Billay, video producer at Queens College of the City University of New York, for his creativity, guidance, and patience. By providing translation services, Emiko Mizunuma and Akihiko Takahashi were instrumental in bringing meaning to the many hours of videotape footage. I am most grateful to Yoshihiko Hashimoto and Toshikazu Ikeda, at Yokohama National University, for their guidance, advice, and suggestions throughout the development of the videotape and *User's Guide.*

Thanks are due to the American seminar participants who generously shared their notes from the lesson study sessions held in Japan: Angela Giglio Andrews, Shelley Kim Ferguson, Jackie Hurd, and Carol Midgett.

Special thanks are extended to Victor Entertainment, Incorporated, for permission to use the "Counting Song Variations," from *Spring Ocean* CD, and to MicroFrontier for permission to use the image of the vinca flower. Hiromu Ohno is acknowledged for designing the seminar logo used throughout the videotape; the logo is found as the background design in Appendix 1.

The support of the Division of International Programs of the National Science Foundation is gratefully acknowledged. Appreciation is expressed to J. Spud Bradley, National Science Foundation, and John Thorpe, former executive director of the National Council of Teachers of Mathematics, for their advice throughout the ICME-9 Travel Grant Project.

What Is Japanese Lesson Study?

Japanese lesson study, practiced in Japan for the last several decades as a means to promote and achieve inquiry-based teaching (Lewis and Tsuchida 1998; Yoshida 1999a, b), was introduced to the American education community and the general public as a result of the Third International Mathematics and Science Study (Stigler and Hiebert 1999; Yoshida 1999a, b). Although different types of lesson-study experiences exist (e.g., research lessons), the major characteristics are the same: collaborative planning, teaching and observing, analytic reflection, and ongoing revision. A few times each academic year, teams of teachers invest many hours in discussing and planning a lesson that supports a common goal across disciplines (e.g., to develop independent problem-solving skills); observing students working during the implementation of the plan by one of the team teachers; and reflecting on the lesson, leading to a revised plan.

In Japan, mathematics lessons typically scheduled for forty-five minutes in elementary school and fifty minutes in secondary school (Shimizu 1999) are characterized as being open-ended (Becker and Shimada 1997; Hashimoto 1999). A nontraditional, nonroutine problem is posed to challenge students' thinking and to elicit various problem-solving strategies. At crucial points during the lesson, key, pivotal questions are posed to students to provoke higher-order thinking (Shimizu 1999, p. 109). Through using selected work of the students, the main mathematical idea of the lesson is carefully summarized by the teacher.

In Japan, lesson study in mathematics is typically practiced in the elementary and middle grades. Several variations of lesson study are possible: (1) Lesson study may occur at the school level where teachers at the same grade level (e.g., grade 2) or in the same content area (e.g., mathematics) meet to plan a lesson. One of the team members teaches the lesson while the others observe the lesson. (2) Lesson study may occur at the school-district level, where teachers from different schools plan the lesson and one of the teachers conducts the lesson in his or her class while the others observe. (3) Lesson study may occur on a larger scale for conferences and meetings, similar to the one depicted in the videotape, held at the University of Tsukuba Elementary School.

Regardless of the variation, for the most part, the phases of a lesson study are collaborative planning, teaching and observing, analytic reflection, and ongoing revision (see Appendix 2 for a transparency template). A description of each phase related to the grade-2 example in the videotape follows.

Collaborative Planning

During collaborative planning sessions, which often are scheduled after school, a team composed of teachers who usually teach at the same grade level or in the same content area meet to discuss the broad common goal (e.g., to develop independent problem-solving skills) and ways to translate the broad goal into a specific objective for a lesson. Ideas for lessons are discussed with respect to a unit of study. In the videotaped example, concepts of measurement and capacity, number relationships, and spatial visualization were topics that were integrated in response to new instructional guidelines that the teacher, Mr. Tsubota, explained were issued by the Japanese Ministry of Education. The detailed lesson plan includes background information of concepts preceding the introduction of the lesson to be observed; the main activities and structure of the lesson, which include posing a problem, allowing students the opportunity for individual problem solving, whole-class discussion, and a summary; students' anticipated responses; and remarks on teaching (Shimizu 1999; see detailed lesson plan, pages 9–14). Students' anticipated responses are built into the lesson plan to assess "individual concept formation" (Nagasaki and Becker 1993, p. 48).

Teaching and Observing

When the plan is completed after several in-depth collaborative planning sessions, one of the team members teaches the lesson. In the videotaped example, Mr. Tsubota introduced the lesson by presenting a game involving an eight-by-eight grid, on which children had to position pentominoes that they had constructed in a previous lesson (see figs. 1 and 2). The challenge was an open-ended problem to determine whether the twelve pentominoes could fit on the eight-by-eight grid (see lines 8–10 in the "Selected Excerpts" section). After listening to several conjectures posed by the children, Mr. Tsubota presented them with various shapes, asking them to predict and then determine whether the shapes could be completely covered with pentominoes.

In some lesson studies, only the other team members, or a group of teachers from the school or other schools, observe the lesson. In other lesson studies similar to the one presented in the videotape, more than 600 teachers observe the lesson. Teachers who observe the lesson typically follow a protocol (see Appendix 3). They do not interact with the teacher or the students. They focus on an aspect of the lesson and record their observations for the postlesson discussion.

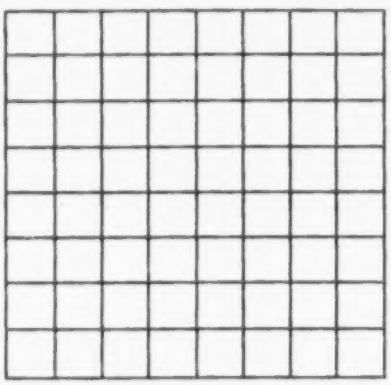

Fig. 1. 8 × 8 grid for pentomino game

The teacher may have several reasons for questioning children during a lesson: to assess students' understanding and to promote students' thinking (Yoshida 1999b). In the videotaped example, as recognized and complimented by an American observer, Dan Teague, Mr. Tsubota's questions were carefully crafted to promote and to elicit children's thinking (e.g., see lines 18, 20, 73, 76, 78, 101, 119, 131, 138, 153,157, 188, 190, 206, 216, and 240).[1]

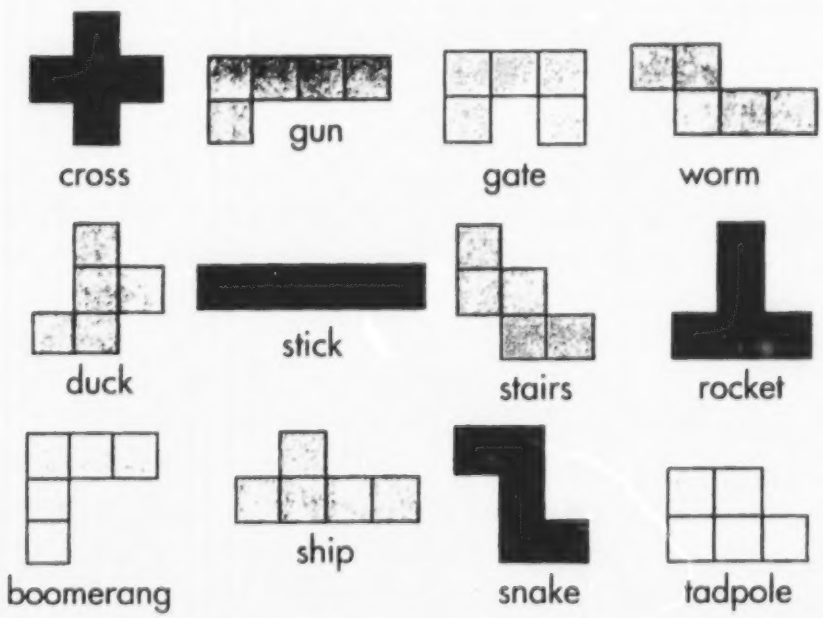

Fig. 2. Twelve pentominoes created and named by the second graders

Thirty-seven children worked individually and together to solve the problems. Many of them were called to the board to explain their thinking (see the "Selected Excerpts" section).

By the end of the lesson, the children were able to analyze a shape to determine whether it could be covered by pentominoes by ascertaining whether the shape was composed of a multiple of five squares. The children were able to write number sentences or formulas to express their reasoning.

Analytic Reflection

Once the lesson is over, the teacher and the observers collect their thoughts and have a debriefing session. One of the planning teachers acts as a moderator for the postlesson discussion. The debriefing and reflection begin with the teacher's sharing his or her impressions of the lesson (see Appendix 3 for a lesson study protocol).

In the videotaped example, Mr. Tsubota described how his lesson integrated number and geometry—specifically number relationships and spatial visualization (see fig. 3). He mentioned that as he walked around observing the children, he was thinking about those whom he would like to call to the board to share their ideas. He emphasized that both incorrect and correct answers are important for sharing and for learning.

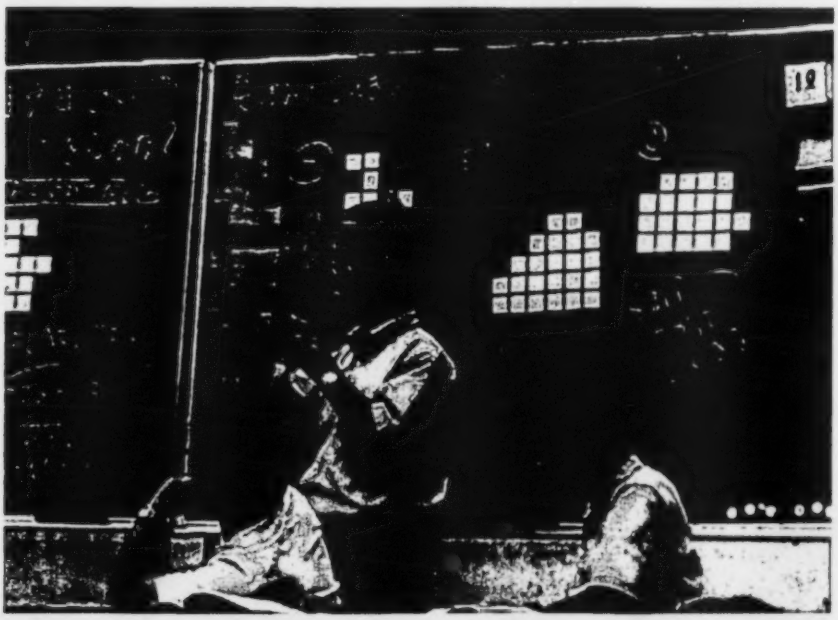

Fig. 3. Photo of Mr. Tsubota sharing his ideas about the lesson at the postobservation meeting

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Once Mr. Tsubota had a chance to share his impressions, other teachers on the panel posed questions and commented on the lesson (see fig. 4). Most of the comments highlighted elements of *Professional Standards for Teaching Mathematics* (NCTM 1991). In particular, questions and comments were related to the task and connections with previous and subsequent lessons, the purpose of the lesson and whether it was accomplished, students' responses and the discourse reflecting children's level of understanding, and the mathematical connections between spatial and number concepts. An unidentified teacher in the audience described Mr. Tsubota's approach as nonauthoritarian, as he elicited important ideas and relationships from the children. He also said that Mr. Tsubota was skillful in guiding students to attain the goal of the lesson, clarifying essential points that may not have been evident to all the children. The Americans participating in this lesson study conference witnessed "constructive professional criticism delivered with etiquette and grace" (Curcio 2001).

Ongoing Revision

Ideas for revising and extending the lesson emerge from the postlesson discussion. The suggestions for Mr. Tsubota included reintroducing the game that the students played at the beginning

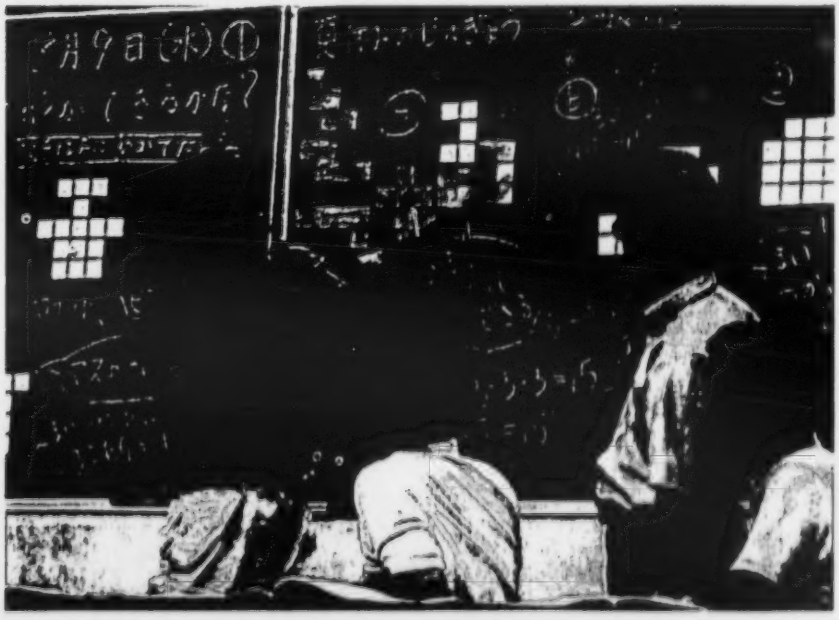

Fig. 4. Teachers on the stage discussing Mr. Tsubota's lesson during the postobservation meeting

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of the observed lesson (i.e., filling the eight-by-eight grid with the twelve pentominoes and asking students to analyze whether the twelve pentominoes can cover the grid). By expressing the number sentence $5 \times 12 = 60$, students can conclude the possibility of covering the grid with the twelve pentominoes so that no pentomino extends beyond the border, because $64 > 60$. Four squares on the game board would remain uncovered. By guessing and checking, students could obtain several correct solutions.

A suggestion was made to extend the lesson by asking students to organize the twelve pentominoes on the eight-by-eight game board so that the four squares that remain uncovered form a tetronimo. In a follow-up lesson, the teacher may also consider presenting hexominoes.

Typically, a revised plan is developed and another teacher on the planning team teaches the revised lesson; the process continues as the teachers "polish" their instructional strategies. As a product of lesson study experiences, Japanese teachers publish their lesson plans (Yoshida 1999b).

Can Lesson Study Work for *Us?*

Lesson study is an ongoing process that requires time, commitment and perseverance, and support. Time for teachers to meet and to plan lessons can be incorporated into the regular school day during preparation or lunch periods or be scheduled after school. A commitment on the part of teachers is essential to the success of studying lessons, as they control the design of their professional development experiences and persevere in effecting change. As with any form of professional development, the support of administrators and supervisors is essential for promoting reform efforts.

Trying to transplant ideas from another culture without making appropriate modifications to meet the needs of teachers in American schools is not advised. However, "lesson study embodies many principles of effective professional development...for example, it is embedded in the classroom and focused on students, it is collaborative and ongoing, and it is based on teachers' own concerns and questions" (Stepanek 2001, p. 3).

Lesson study "honor(s) the central role of teachers" (Lewis 2000). Taking an active role in professional development contributes to building teachers' positive attitudes and willingness to take risks in instruction. By analyzing mathematics content, discussing instructional strategies, and anticipating students' responses to tasks and activities, novice teachers working with expert teachers can build and strengthen their mathematical content knowledge and pedagogical strategies. During a lesson observation and postlesson analysis, the content continues to be analyzed as strategies for teaching are also examined. Furthermore, unlike the traditionally evaluative connotation given to formal observations, since the focus of the observation is on the lesson plan and students' work rather than on the teacher, teachers experience nonthreatening visits by colleagues and guests.

Although not to be viewed as a panacea for all that ails our schools, lesson study is being implemented in districts around the country (e.g., Bellevue, Washington; Nashville, Tennessee; Community School District Two, New York City). Administrators are finding ways to bring teachers together to support the concept of lesson study as a means for ongoing professional development. (See Web site addresses of some of the districts on page 30.)

The notions of detailed planning and anticipating students' responses may not receive as much attention in the United States as they do in Japan. By pooling their experiences and resources, teachers can build on their accumulated knowledge base and strengthen the development of a lesson plan. Such an approach would serve students very well.

Some Questions to Consider

As a result of observing and designing lesson study sessions, several questions will need to be examined and discussed as providers of professional development think about adapting lesson study ideas in the United States:

- How can American values related to teacher individuality and creativity be capitalized during lesson study experiences?
- How can a team teacher who agrees to teach a plan developed by the team acquire "ownership" of the plan rather than feel inept during its implementation?
- With the widespread availability of "teacher-proof" materials, how can teachers be convinced to invest time in what may seem to them as "reinventing the wheel"?

Testimony for Lesson Study

For every reason that teachers may find to avoid professional development, a multitude of positive attitudes toward the lesson study approach are found. In particular, as Ms. Sato, a relatively new teacher interviewed on the videotape, testifies, lesson study has helped her develop a deeper understanding of mathematics while gaining a greater knowledge of her students. Through this process, she is able to anticipate students' responses and create better lesson plans.

Mr. Tsubota indicates that he learns from the many observers who visit his classroom. He believes that observers are in an advantageous position to make valuable suggestions, providing insights into the many connections among children, the teacher, mathematics, and the classroom experience (see fig. 5). His remarks remind us that "lesson study is not about perfecting a single lesson, but rather, it is about improving teaching."

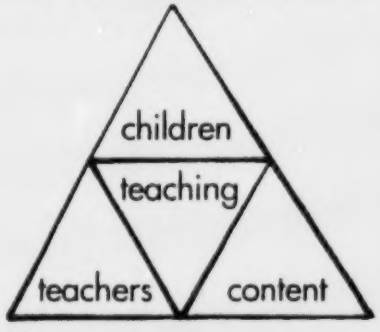

Fig. 5. Mr. Tsubota's scheme about teaching

Detailed Lesson Plan[2] of the Grade-2 Video Clips

Location: Elementary School attached to Tsukuba University[3]

Teacher: Mr. Kozo Tsubota

Date: Wednesday, August 9, 2000

Number of Students: Thirty-seven

Grade: 2

Topic: Introductory, hands-on mathematics lesson emphasizing an integrated approach to number operations and spatial visualization

Time: Forty-five minutes

Broad Goal: To develop independent problem-solving skills

Aim: To integrate number operations and spatial visualization by exploring with pentominoes

Overall Objectives for Several Lessons:[4] Children will do the following:

- Know that 1 liter is a shape that is 10 cm by 10 cm by 10 cm, through comparing quantities
- Make their own container that has a capacity of 1 liter
- Explore how to arrange a net of five squares (i.e., pentominoes) to make a box shape
- Determine which nets can be used to make a box shape and which ones cannot be used to make the shape
- Explore ways to arrange subsets of the twelve pentominoes on templates and explain numerical relationships, calculating quantities using addition and multiplication
- Think, using their hands
- Explain logically
- Apply previous knowledge and understandings related to quantities and the shape of a box
- Indirectly relate pentominoes to multiplication (i.e., multiples of 5) and compare sizes

The hands-on activities not only will be useful to understand pentominoes but will also help learners relate to quantity, understand the shape of a box, and develop multiplication sense by using a diagram. The activities and materials will support learners in making connections.

Second-Grade Instructional Plan

Research Theme: Examine ways to integrate arithmetic instruction with spatial visualization by using hands-on mathematics.

1. About the research theme—relations with other content areas

(a) *Learning about quantity*[5]

To measure the capacity of a container, amount of water, and so on, students will learn the units of measure "l," "dl," "cl," ml." To do so, students will use containers that are available in the classroom. However, in this study, students not only use things already in existence but also create containers with which they can represent the units of measure. In other words, we decided to have the children make containers using handcrafting paper (see fig. 6).

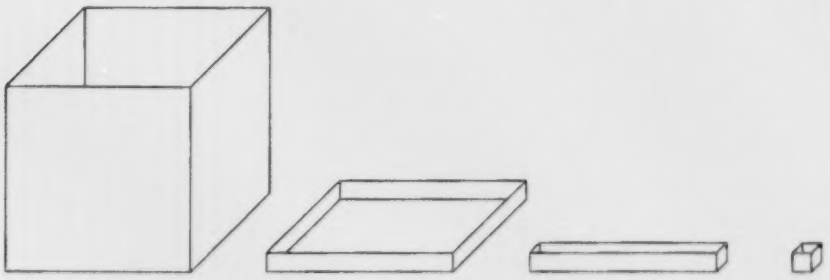

Fig. 6. Containers created by the second graders during a previous lesson

(b) *Considering how to make a cube*

To realize that a cube that measures 10 cm × 10 cm × 10 cm is 1 liter, students actually make the cube with handcrafting paper. In the process, students become aware that five squares measuring 10 cm × 10 cm are necessary to make an open cube. The problem with this task is how they put together the five squares. Many heads are better than one, so collaboration is encouraged. Students find that they can use many ways to make a cube. This question is an open-ended investigation for the children.

Using a guess-and-check strategy, students search for the ways of making a cube. By manipulating the nets of squares, each student is able to find the ones that can be used to make a cube.

Students will be able to find eight ways to make a cube. Children examine the pentominoes and give a name to each of them (see fig. 2). Students find four pentomino patterns that cannot be used to construct a cube.[6]

(c) *Playing with pentominoes by presenting a covering game for "polishing" figure sense and spatial visualization*[7]

Hands-on mathematics activities: In the new instructional guidelines,[8] activities that involve students' working and experiencing are emphasized. For the subject of "arithmetic," "arithmetic activities" have been designed. These arithmetic activities are not limited to the activities of using or making things. They also comprise a series of experiences that were prompted by children's interests and by such student comments as "Oh?" "That's strange," and, "I want to try," reflecting their desire to find out. The process of exploration contributes to children's problem posing.

Such a series of experiences is the real "activity," called "hands-on mathematics." Here, since the students are in the lower grades, they do activities by using concrete objects and create images by manipulating the objects. Moreover, the activities, in which the students place on different templates the pentominoes that they created, are considered to accomplish one of the goals of arithmetic for the lower grades—that of developing spatial visualization.

2. Development of the lesson

(a) *Objectives of the lesson*

Students will be able to (1) recognize which shapes are possible to cover with pentominoes and which shapes are not possible to cover with pentominoes and (2) explain the reason why some shapes can be covered and others cannot be covered.

(b) *The plan*

Steps[9]	Main Learning Activities	Students' Anticipated Responses	Remarks on Teaching
Posing a problem	1. Game to begin the lesson: Try to cover an 8 × 8 grid with pentominoes without overlapping or extending beyond the borders.	When children are told that the board is "a Sumo ring," they will connect it with Sumo and easily understand the concept of the game.	1. In the game, students take turns placing different pentomino shapes on an 8 × 8 grid (see fig. 1). The game is over when any of the

Steps	Main Learning Activities	Students' Anticipated Responses	Remarks on Teaching
			pentominoes that remain cannot be placed on the grid without having overlaps or pieces extending beyond the perimeter of the grid. Since this game makes students think which figure fits in the spaces, they naturally "polish" their sense of figures.
	2. Try making the given shapes using some of the pentominoes. Challenge students to determine whether pentominoes can be arranged to fill the shape without overlapping or extending beyond the perimeter.		2. Show the shapes made of 2 or 3 pentominoes, and get students to make the same shapes. Although the children have not yet studied the multiplication tables, they are familiar with using multiplication for continuous addition. Consequently, they know that "$5+5+5=5\times3$."[10] Using this knowledge, they can explain with a mathematical formula whether it is possible to make a figure out of pentominoes. I would like to adopt this approach in class.

Steps	Main Learning Activities	Students' Anticipated Responses	Remarks on Teaching

Students' individual problem solving	Make figures with pentominoes (logical explanations using a formula involving multiplication or continuous addition). Give students templates (e.g., flower, air pump, plant pot) that are progressively harder, one at a time, to fill in by combining pentominoes that they select.	flower = gate + rocket;
		$5 + 5 = 10$;
		$5 \times 2 = 10$
		air pump = rocket + snake + duck;
		$5 + 5 + 5 = 15$;
		$5 \times 3 = 15$
		plant pot—pentominoes do not fit exactly; students will realize that this shape cannot be covered exactly with pentominoes and consider the reason for it:
		$5 + 5 + 3 = 13$;
		$5 \times 2 + 3 = 13$; or
		$5 \times 3 - 2 = 13$.
		This shape does not contain a multiple of five squares (see fig. 7).
			Each student has his or her own set of pentominoes to explore and solve problems. When students become used to making shapes composed of a combination of pentominoes, raise their awareness of shapes not formed by a combination of pentominoes.
			In the classroom, we deal with the figures for $5 \times n$ and the figures for $5 \times n + a$ at the same time, because I would like to focus on the situations in which the children express "why it is not possible."

Whole-class discussion	Children explain solutions to the class at the board.	Plant pot: "It's not possible, because the shape has three more squares than two pentominoes." "It does not make 5×3." "It is less than three." It is less than 3 fives." "It is less than 5×3."	First get students to determine whether the shapes can or cannot be covered using the pentominoes, and then have children cover the shapes.
Summary (Exercise/ extension)	Children explain reasons.	Pentominoes fill shapes that have a multiple of five squares.	1 pentomino → $5 = 5 \rightarrow 5 \times 1$; 2 pentominoes → $5 + 5 = 10 \rightarrow 5 \times 2$; 3 pentominoes → $5 + 5 + 5 = 15 \rightarrow 5 \times 3$;

Steps	Main Learning Activities	Students' Anticipated Responses	Remarks on Teaching
			4 pentominoes → 5 + 5 + 5 + 5 = 20 → 5 × 4. Have students notice that the number of squares for the plant-pot template is not a multiple of 5. Have students notice that the number of pentominoes is determined by number of squares, because every five squares is one pentomino.

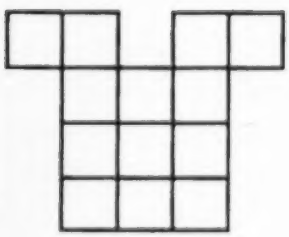

Fig. 7. Plant-pot figure

Translation of Selected Excerpts of the Grade-2 Lesson[11]

[Mr. Tsubota (*T*) directs the children (*C*) to move from their seats to the center of the stage to play a game. Using pentominoes that they had created, the children are to cover an 8 × 8 grid without overlaps.]

T: Try to arrange the twelve pentominoes on the grid without overlaps [see fig. 1]. Once a shape is used, you may not use it again.

[Children take turns selecting a pentominoe and posting it on the grid (see fig. 8).]

T: [After children have used most of the pentominoes] There's a space—do you think you can fit a pentomino there?

C1: No.

T: Why don't you think a pentomino will fit there?

C1: The shape that fits was used already.

T: What do you notice about the spaces that still need to be filled?

C2: To make the pieces fit, maybe we need to put them in another way.

[After about five minutes of "play" and informal discussion, Mr. Tsubota directs the children to return to their seats.]

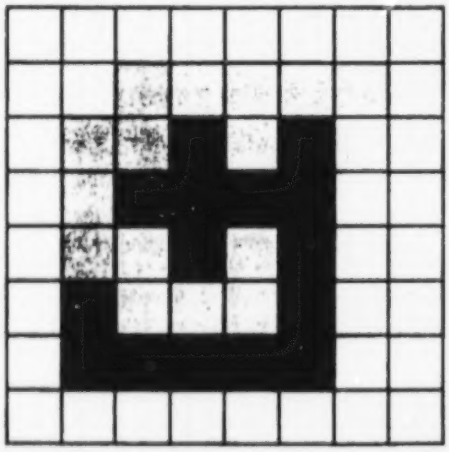

Fig. 8. An 8 × 8 grid with several pentominoes attached by the children

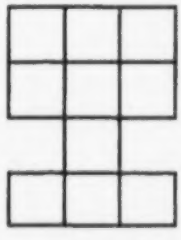

Fig. 9. Flower shape

T: Take out your notebook. Write down the date on the top, "August 9th, Wednesday" [he writes this date on the chalkboard]. [Title:] "Summer class…"
T [writes]: "Can we create this type of shape?" [flower shape that the students have seen, created, and studied before; see fig. 9]
C3: I think it is a rocket.
T: What is a "flower" in English?
C4: Flower.
T: Oh, you know it well. In the game we played earlier, after using some of the pentominoes, there was a space. Can you cover the flower shape without having any empty spaces?
[Teacher shows shapes that children learned already and posts them on the chalkboard.
Children have named the shapes, and they recite them aloud in unison as they are posted on the chalkboard. See fig. 2.]

T: Is it possible to put 1 of these shapes into the flower and cover the spaces?
C5: I don't know until I try.
C6: Absolutely.

[Teacher has the same shape, the flower shape, printed on sheet of paper. He holds it up to the class. Copies are handed out to the children.]
T: Try different shapes to cover the flower-pot shape.
C6: I made it.
T: Someone come here to put it up. [Children raise their hands enthusiastically, volunteering to be called to the board.]
T: One person, one shape.
[A boy places the rocket pentomino on the flower shape. Then a girl places the gate pentomino and completes the task.)
C7: Turn it.
T: And like this? [He adjusts the gate pentomino.]
C7: No. [He rotates the entire flower shape; see fig. 10.]
T: To make a flower shape, we used the rocket and the gate pentominoes.

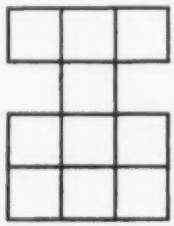

Fig. 10. Rotated flower shape

70 [Mr. Tsubota posts the air-pump shape on chalkboard.
71 Some children say it is not an air pump. It doesn't look
72 like an air pump. See fig. 11.]
73 *T*: Is it possible or not possible to cover this shape exactly,
74 and why or why not?
75 *Several children* (in unison): It's possible.
76 *T*: With which shapes?
77 *C8*: With the rocket.
78 *T*: How could you make it?
79 *C9*: Duck.
80 *T*: He can make it with the duck.
81 [Mr. Tsubota distributes template of air-pump shape.]
82 *C9*: It's possible to make it with the duck.
83 *C10*: All are upside down.
84 *T*: What do you mean?
85 *C10* [explains at the board]: All are upside down.
86 *C11*: Use duck and rocket flipped.
87 *T*: All upside down—what does "upside down" mean?
88 [Two children go to the board to demonstrate.]
89 *T*: So you flip it?

Fig. 11. (*a*) Air-pump figure and (*b*) air-pump figure partially filled in

C11: No it's a turn [Mr. Tsubota tries to follow the child's directions and make it fit on the shape. The teacher writes "up" and "down" on the chalkboard. He asks for an explanation in words for "turn up" and "down."]
C12: We don't have to turn. It's possible without turning.
T: OK, someone try it. Someone with confidence, try it.
[Teacher puts duck pentomino on shape.]
T: Anything? [pause] OK, this is a duck pentomino turned. Anything else?
[Child takes rocket pentomino from first example, rocket turned.]
T: Also the rocket is turned. [pause] I wonder what fits in the space?
C13: Snake.
T [asks for someone to put the snake up.]: Someone put it in. Is the snake going to be turned? [Asking before the child tried.]
[Child puts up the snake pentomino as it is.]
T [to the class]: Did the snake become turned?
T: If a duck goes to the left, the snake should be turned [using the same word for "upside down" and "flipped"].
T: Let's try it.
C5: I can't.
T: It's hard to do. [Then she makes it.] Oh [impressed], I see.
T: [Referring to the flower] This part [top of flower] is very easy. Let's try a more difficult one. [Teacher writes on board, "rocket and snake and duck" for air container.]
C7: No, isn't it four? Can we make it out of four?
T: Why do you think so?
C7: The first time it [i.e., the flower] was made with two. The second time it [i.e., air pump] was made with three.
T: It seems as though he has an idea.
T: [Placing plant pot shape on board] What does this look like?
C14: It looks more a dog than a plant pot. [Teacher changes name on board to "dog face."
T: I know it looks like different things to you, we know it's a dog face. Is it possible to make a dog face with what you have now? [See fig. 7.]

T: Do you think it is possible to make it with four? [Teacher

tries to get answer from child.]
C7: No, it's not possible.
T: [Repeating child's response.] It's impossible with four.
C15: It's possible with three.
T: [Over child's shoulder] OK, please raise your hand. Who thinks it doesn't need four?
Is it possible to make it with three?
[Child has a question—counting the squares; this has five squares, dog face.]
C16: If it has three, it can fit.
T: We don't know what you mean.
Others (in unison): I understand.
T: Who can explain it more understandably?
C17: One pentomino has five squares, so if you use one pentomino, it has five; if you use two, it's ten; and if you use three, it's fifteen. [Girl sitting next to child responding nods in agreement.]
T: Did you hear him? Do you understand?
Others (in unison): Yes, I understand.
T: Hearing and understanding are different. [Teacher asks whether one of the children understands.]
T: Is there anybody who doesn't understand what was said?
Several children: Yes.
T: Are there any who understand? [Children raise hands.]
T: Is there anybody who can explain understandably what the first and the second one said? [Teacher points and calls on students by name.]
C18: What Alakowa is saying, for example, if we use three pieces, one piece has five squares. If we use three pieces, 5 + 5 + 5 becomes 15.
T: So, how many pieces did she use?
[*C18* started to write "3 + 3 + 3," then erased it; she then wrote "5 + 5 + 5 = 15."]
T: What about other people, what do you think?
T: Eto gave us a formula. I see. OK, this is the case when we used three pieces.
T: Anyone else?
C5: This [pointing] has five squares always. In this case, 2, 4, 6, 8, 10....
T: Do it again slowly over there.
C5: 2, 4, 6, 8, 10, 12, 13 squares.

T: Oh, you counted well.
[Children count by 2s together in unison.] 2, 4, 6, 8, 10, 12, 13 squares.
[Teacher writes "13 squares" on board.]
C19: That shape, if we count, there are thirteen squares, so even if we use three pieces, it lacks two squares to make fifteen.
[Teacher writes, "If we use 3 pieces, 15."]
C5: There are thirteen squares here. If we use three, 5 + 5 + 5 = 15. If we use three pieces, two squares are left uncovered.
T: There are thirteen squares, but if we use three pieces, there should be fifteen; there are two holes.
T [calls a boy to the board]: Ikeda has something to add.
C19: We can use a different formula.
T: What kind of formula?
C: 5 × 3.
T: What does 5 × 3 mean?
C19: Three 5s.[12]
T: When there are 3 fives, it becomes 5 × 3.
[Child writes 5 + 5 + 5 = 15. Teacher writes on top of this, "If there are 3" and circles it.
T: 5 × 3 is the same as this [referring to the 5 + 5 + 5 = 15].
T: It's OK, even if the formula is different.
T: Then I'll give you a handout. I wonder if it really makes two holes. [He walks around monitoring the children's work.]
T: Really? Are you sure?
T: How many pieces will we use?
T: [He distributes a template; see fig. 9.] Let's try together. When you are done at your desk, I'd like you to go to the board, too.
[Pause]
T: Do you think it's going to make two holes? I wrote some thing wrong, didn't I?
T: Two holes are made.
Several children: Three holes if we use two. [One child repeats this statement.]
T: If we try doing this with two pieces, are there going to be three holes?
T: Did it become so?
T: Is there anything wrong on the board?
Children (in unison): Yes.

T: Why is it wrong?
C20: In fact, there are three holes, that's why. Doing with three, two squares will be left over.
T: "Two holes" on board is wrong. If we use three, two squares are left over, extra.
T: [writes on board] "If we use 3 pieces, 2 holes." [circles 2 holes]
T: And if we use two pieces, three holes.
[At least five children have a chance to try to cover the plant pot shape in different ways.
Children are encouraged to try different pentominoes to cover the template, but each time, three squares remain uncovered or two extra squares are left over on a pentomino.]
[Teacher writes "Possible Impossible" on board.]
[Teacher writes "A B C" on board, then posts three templates; see fig. 12.]

T: Let's find out which one is not possible.
C21: If you use five, A and C are OK, B is not.
C22 [at board]: It's easier if you move this piece [square jutting out] over here [to the top-left-hand corner]. It does not look like it's possible, but we can try to find a way.
T: How did you know you need three pieces for it?
C22: I know from its appearance, $15 = 5 \times 3$.

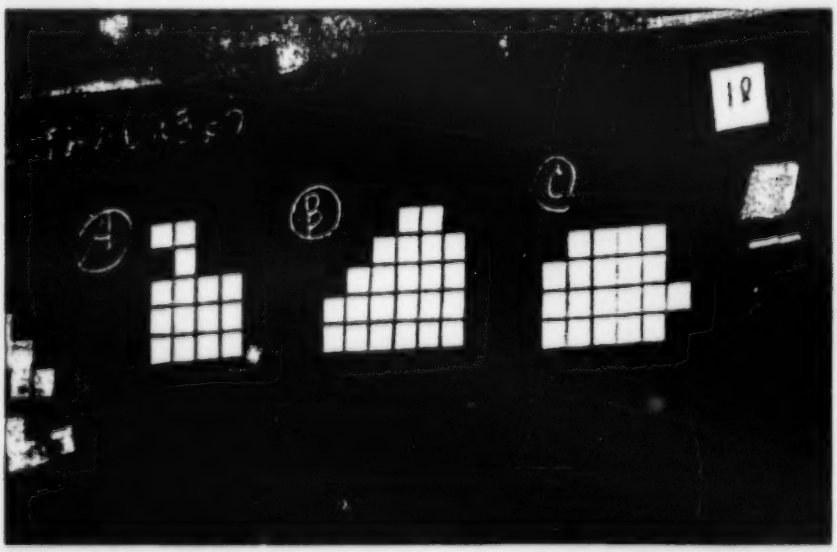

Fig. 12. Three templates posted on the chalkboard as a culminating activity

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APPENDIX 1

List of Seminar Participants

Japanese Seminar Participants

Yoshihiko Hashimoto, *Yokohama National University*
Eizo Nagasaki, *National Institute for Educational Research*
Toshikazu Ikeda, *Yokohama National University*
Kozo Tsubota, *University of Tsukuba Elementary School*
Akira Shimazaki, *Kashiwabara Elementary School*
Akira Takii, *Nakamaru Elementary School*
Kayo Sato, *Setagaya Elementary School*
Masanori Usiba, *Niijima-mura Shikinejima Lower Secondary School*
Hiroko Uchino, *Tsuruda Junior High School*
Hiromu Ohno, *Kamakura Junior High School*
Hiroe Hatta, *Shibuya Kyoiku Gakuen Makuhari Upper and Lower Secondary School*
Masayuki Ishitani, *Kanagawa Sohgoh High School*

American Seminar Participants

Frances R. Curcio, *Queens College of the City University of New York*
Angela Giglio Andrews, *Naperville District 203, Illinois*
Phyllis V. Caruth, *Little Rock Central High School, Arizona*
Shelley Kim Ferguson, *Chula Vista Elementary School District, California*
Jacqueline Goodloe, *Burrville Elementary School, Washington, D.C.*
Jackie Hurd, *San Mateo, California*
Beth Lazerick, *Boca Raton, Florida*
Marilyn Elaine Mays, *North Lake College, Dallas, Texas*
Carol Midgett, *Southport Elementary School, North Carolina*
Mark Saul, *Bronxville School, New York*
Lee V. Stiff, *North Carolina State University*
Daniel I. Teague, *North Carolina School of Science and Mathematics*

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APPENDIX 2

What Is Lesson Study?

1. Collaborative planning

Working with colleagues to—

- identify an important, worthwhile aim to support a school goal;
- develop a plan to achieve the goal;
- anticipate students' responses;
- prepare alternative approaches.

2. Lesson observation by colleagues and guests

Observers—

- do not interfere with the teaching or the learning;
- may ask students informational questions for purposes of clarification.

3. Analytic reflection

Analysis entails—

- the lead teacher's sharing thoughts about the lesson;
- the team members' questioning and commenting about the plan and students' reactions to the plan;
- the guests' and visitors' sharing their observations.

4. Ongoing revision

Refining the lesson entails—

- collaborative planning that integrates ideas from the postobservation discussion;
- lesson observation;
- analytic reflection.

APPENDIX 3

Lesson Study Protocol

*Although some of these protocol guidelines may seem intuitive, many of them are based on the experiences of Japanese teachers who have been doing lesson study for many years and who have formalized this etiquette as a natural part of the lesson study process. This protocol is not meant to minimize the important or reflective nature of the feedback activity but, rather, is meant to help make the process more constructive and efficiently organized.**

Observing the Lesson

1. The observers (including the teachers who helped plan the lesson) should not interfere with the natural process of the lesson (e.g., by helping students with the problem). However, observers are allowed to ask informational questions of students if necessary (e.g., if they could not hear what a student was saying). In other words, communication with students for purposes of clarification is permitted.

Before the Debriefing Discussion

1. All group members should relax and gather their thoughts instead of beginning to immediately discuss the lesson.
2. The group members who taught the lesson should assign roles among themselves to keep the discussion focused and on track. These roles include those of moderator-facilitator, timekeeper, and recorders.
3. The teachers who planned the lesson should sit together at the front of the room in panel formation during the feedback session. The purpose of this setup is to emphasize the idea that the entire group, not just the teacher who taught the lesson, is receiving the feedback.

*Adapted from "Lesson Study Protocol," © 2001, Lesson Study Research Group, Columbia University, under the direction of Clea Fernandez. Please address all requests to cite or use this form to Clea Fernandez, cf170@columbia.edu, at Teachers College, Columbia University. Used with permission.

Protocol for Sharing Feedback about the Lessons

1. The moderator-facilitator should begin the debriefing discussion by briefly outlining the agenda for the discussion. (E.g., "First we will hear from the teachers who planned the lesson, then we will spend the last fifteen minutes hearing from the outside advisors.")
2. The teacher who taught the lesson* should have the first opportunity to comment on his or her reactions to the lesson, followed by the other planning-group members. This format allows the teacher or teachers who taught the lesson to begin by sharing insights about what was being studied, what worked, what did not work, what they would change about the lesson, and so on. If the feedback session occurs after the second implementation of a study lesson, the planning members should clarify what they tried to achieve in the lesson and how these goals were related to changes made between the two lessons. Finally, the planning teachers should direct the observers to give feedback that is related to the focal points, goals, and issues of the lesson.
3. When observers begin to share their feedback, they should begin by first thanking the teacher who taught the lesson, then by talking about what they liked about the lesson. When other observers have shared their critical feedback in the past, they often began by couching their points in such statements as "When I taught a similar lesson ...," or "If I were to teach a similar lesson, I would do (blank) differently because...."
4. Each observer should give other observers the opportunity to comment on similar or related aspects of the lesson, so that everyone who would like to comment has an opportunity to share his or her insights.
5. The teacher or teachers who planned and taught the lesson should wait until *all* feedback about a particular aspect of a lesson has been received before responding to the observers. This waiting etiquette both prevents the discussion from becoming a point-volleying session and allows all participants to voice and absorb the feedback in a reflective manner.

*The lesson was taught by Kozo Tsubota on August 9, 2000, at the National Group for the Mathematics Lesson Study Conference, held at the University of Tsukuba Elementary School.

NOTES

1. Other examples of Mr. Tsubota's questioning technique can be found in Nagasaki and Becker (1993).

2. Translated by Emiko Mizunuma and edited by Frances R. Curcio

3. The lesson was conducted by Kozo Tsubota for the National Group for the Mathematics Lesson Study Conference held at the Elementary School attached to Tsukuba University, August 9, 2000. It was discussed at the Post-ICME-9 Seminar, Analyzing the Teaching of Mathematics in Japan and the United States, at the National Institute of Educational Research, Meguro, Tokyo, August 8–11, 2000.

4. The first four objectives listed were accomplished in a previous lesson.

5. This part of the plan was developed on a previous day.

6. The shapes that can be folded into an open cube are the cross, the gun, the worm, the duck, the stairs, the rocket, the ship, and the snake.

7. The lesson for the lesson-study observation began at this point.

8. The new instructional guidelines refer to policy documents issued by the Japanese Ministry of Education.

9. This lesson-plan format illustrates the style described by Shimizu (1999).

10. For the Japanese, 5×3 is interpreted as "3 groups of 5," or "5 repeated 3 times."

11. The lesson was taught by Kozo Tsubota on August 9, 2000, at the National Group for the Mathematics Lesson Study Conference, held at the University of Tsukuba Elementary School. Dialogue excerpts were translated by Emiko Mizunuma and edited by Frances R. Curcio.

12. In Japan, 5×3 means 3 groups of 5, or $5 + 5 + 5$.

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Japan–United States Elementary Education Research Project at Mills College: lessonrsearch.net

LessonLab: www.lessonlab.com/

Lesson Study Research Group at Teachers College/Columbia University: www.tc.edu/centers/lessonstudy/

Mid-Atlantic Eisenhower Consortium for Mathematics and Science Education: www.rbs.org/ec.nsf/pages/L2TIMSS; www.rbs.org/ec.nsf/pages/JourneyBeyondTIMSS

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